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CHANGES OF FOREST SITE AFTER CLEAR CUTTING IN SPRUCE FOREST

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Abstract

Within the framework of the UNESCO Man and the Biosphere programme,the ecological effects of clear cutting were studied in an artificially established spruce stand in the region of the Drahanská Uplands. The amount of elements removed from the ecosystem due to the cutting of the aboveground tree biomass was estimated as well as effects of machinery on the change of physical properties of the forest floor, development of decomposition processes of surface humus on the felled area and the effect of the herb vegetation of the felled area on the recovery of physical properties of soil as well as new cycling of elements.

INTRODUCTION

Ecological effects of clear cutting bring about discussions, similarly as the growing of spruce in pure stands. It was especially the extraction of whole trees from forest stands that resulted in a critical approach to this method. Discussions carried out from the viewpoint of influencing the forest environment including the cycling of elements are oriented particularly at the following problems :
/1/ whether clear cutting, in which heavy machinery is used,does not affect too much the physical properties of soils
/2/ whether the removal of whole biomass of the aboveground part of the forest stand from the ecosystem does not disturb the cycling of nutrients and their total balance due to one large output of elements
/3/ whether the removal of the plant cover does not markedly disturb the hydrological function of the forest landscape and thus cause a dangerous soil erosion and increased leaching of nutrients into ground water
/4/ whether the rapid mineralization of a large amount of humus does not considerably increase the input of N/NO_3 into ground water.

The Act of the Czech National Council about forest management and administration in forestry No.96/1977 of the Digest permits clear cutting up to 3 ha in planned cutting, and in damaged forest stands, on sandy soils of pine growing regions and in conversions of forest stands up to 5 ha. That is why in 1977, in the forest enterprise Rájec-Jestřebí, an ecological experiment was established employing clear cutting in a spruce stand and the method of extracting the complete biomass of the aboveground part of the stand.

In literature, there is considerable amount of information on the effects of clear cutting on the change of physical properties of the forest site. So for instance Ivanov/1976/ publishes that compactness, as a consequence of the used machinery, changes according to year's season in dependence upon the soil moisture. In the first year after cutting the soil becames more settled /percentage of porosity is lowered/ and with increasing vegetation on felling areas the subsequent soil regeneration occurs in the second and next years. The time needed for regeneration is given 5-15 years, according the sort of the soil.
Kreutzer and Reemtsma/1979/ consider the question of the output of nutrients in an ecosystem by the whole tree method of cutting in connection with storage of available nutrients in the root zone. Using this method on some sites /mostly poor ones/is considered by them as a cause of lowering the productional conditions.

As a first factor, conditioning the increased movement, if need be the output, of nutrients on felling areas is the change of water balance and the change in the temperature regime of the soil. This question was studied for instance by Troedson and Utbult /1974/ who came to the following conclusion :
The surface runoff generally increases after clear cutting. Mature stand dessicates the soil and that is why there is an excess of soil water on the felling area. This excess must be drained, if we want to have success in forest regeneration. Questioning the change of water balance on felling areas, Likens and Borman /1974/ publish that the yearly water runoff on the felling area was in average 30 percent greater.The quality of water mostly changes with the increased runoff, especially by the increased content of soil suspensions. According to experiences, the increased content of soil particles in runoff water is initiated especially by the construction of skidding roads.

Of course, from the cycling of nutrients point of view, we are interested mostly in processes of the output of nutrients from the soil. Likens and Borman/1974/ publish that concentration of nutrients increases significantly during 5 months after cutting in all main ions, especially in NH_4 and SO_4. Concentration of other soluble substances reached the top during the second year. Losses of NO_3-N were 340 kg from 1 ha during the 3 years after cutting.

The authors further publish that the average net output of all soluble anorganic elements increased during the 3-year period ten times, compared to the long-term average from the undisturbed ecosystem. The increased movement of potassium is conditioned besides the increased outwashing ability of water also by the increased occurence of brushwood after cutting, from which it is outwashed too.

It is clear, that the clear cutting way of wood harvest increases especially the decomposition processes, by opening the soil surface for a direct input of light and moisture. An opinion is known, after which the surface humus during the first year of decomposition increases the N-content by the increasing of the number of nitrogen fixing bacteria. The higher content of nitrogen may result in transient immobilization of phosphorus and potassium in the microbial mass. After dying off of these organisms, potassium and phosphorus and additionally fixed nitrogen are at disposal for leaching. An increased output of nitrates publish also Hornbeck and Kropelin/1979/ especially in streams, their concentration risen from 1.0 mg/l^{-1} to 95 mg/l^{-1} /in broadleaved forests/.

A significant factor, which may significantly influence the soil processes and migration of nitrates in the soil profile especially, after clear cutting, is occurence of vegetation on the felling area. So for instance Boring, Monk and Swank /1979/ publish that in conditions of deciduaous forest of the Appalachian Mountains the net vegetation production on the felling area in the first year after cutting was 1.791 kg/ha, which was 20 % more compared to the control area. These plants distinguished especially by the increased concentration of nitrogen and potassium. It means, that this process minimizes hydrological losses of nutrients and is an initial phase of their new cycling.

Even when on the basis of hitherto information, gained especially in the last 10 to 15 years, it is possible to judge on some generally valid ecological consequences of clear-cutting management, we may agree with the conclusion made by Carlisle and Methven /1979/, that the harvesting of wood in a clear cutting way may, in a long rotation, but need not be the cause of the deficit of nutrients. It will be dependent on the concrete forest ecosystem, especially on their span of stability in this direction.

Characteristics of the experimental station

The research station is located in the forest enterprise Rájec nad Svitavou in the Drahanská Uplands at the altitude of 620-640 m. The territory is covered by deluvial loams with boulders of about 1m in size. The thickness of the layer varies and in the exposure a relatively deep weathering of the granodiorite is evident.

Climatically the territory can be included into the moderately warm and humid region with a relative annual temperature of 6.6°C and annual precipitation of 683 mm. The whole territory is covered by soils of the acid brown forest soil types. The weathered granodiorite without marks of any disturbance of the structure reduces the permeability of the soil subsurface and causes occasional waterlogging of the soil profile and in some places even gleying. The content of clay in the soil ranges within 38-45 %; the soils can be classified as loamy soils. Due to the character of the parent rock and surface humus , the soil is acid. The pH is lowest in the H- and A-layers, i.e. 3.8 and 3.7, respectively. The saturation of the absorbing complex is low and on average amounts to 13, 16 and 43 % in horizons A, B and deeper horizons /B/,Cd, respectively. Humus is accumulated especially in the A horizon /12%/ and then its content rapidly decreases. The surface humus was indicated as mor moder. The highest accumulation of organic matter was observed in the H-layer followed by F- and L-layers, i.e. 22 319, 15 799 and 11 552 kg/ha respectively. The total dry mass of surface humus is ca 50 t/ha. The content of gravel is a characteristic feature of soil profile, particularly in the B-horizon. In the A-horizon, granodiorite boulders often project to the soil surface.

The stand investigated in detail from the viewpoint of the amount and structure of the biomass /Vyskot,1979/ and the summary characteristics were estimated : dry matter of the aboveground part of trees, dry matter of the underground part of trees and dry matter of total biomass, i.e. 273.43, 40.54 and 313.97 t/ha, respectively.There are 1332 trees per ha. From the data of Vyskot /1979/ it can be seen that this 70-year-old stand has a relatively large number of trees per ha. As mentioned by Vyskot, apparently no low thinning was done in the stand so that the stand had a multi-storeyed canopy in the crown layer. Of data on the biomass structure interesting is also the mass of needles amounting to 20 600 kg/ha /Vyskot,1979/.

Results

The initial stage of the experiment was aimed at the following problems :
/1/ determination of the amount of nutrients removed through cutting
/2/ destruction of soil surface, particularly surface humus and rate of decomposition
/3/ change of physical properties of soil and development of their recovery
/4/ characteristics of soil solution and influencing the cycling of elements by herb vegetation on felled area.

On the basis of preliminary results the following was found :

1/
By harvesting the whole aboveground part of the stand the following amounts of elements were removed : N 413, P 75, K 370, Ca 789, Mg 95, S 176, Fe 115, Al 11, Si 409, Cu 1.8, Zn 8.8, Pb 3.5, Mo 3.8, B 1.9 and Mn 219.7 kg.ha^{-1}.
However, the total output of elements during tending of spruce pure stands is even higher.Marion/1975/ states that through tending felling as much as 30-47 % of the value of the total biomass can be taken. This means that the output /yield/ of the main bioelements during the whole development of the stand would be :
510 kg of potassium, 570 kg of nitrogen, 1 088 kg of calcium, and 103 kg of phosphorus per ha.

2/
The reserve of surface humus in the closed stand before felling was about 50 t per ha and was relatively homogenous. Logging was done using the whole-tree method, i.e. cutting with a power saw and skidding of whole trees with a wheeled tractor to a trimming machine. Due to cutting and skidding of trees the natural layering of surface humus was destroyed.

a/ On the main skidding trail nearly all the surface humus was swept away and the mineral surface of the soil was exposed.
b/ In the most of the area litterfall was mixed with detritus.
c/ Skidding of whole trees caused that humus was accumulated especially to stumps and their buttresses.
d/ During artificial regeneration made by an RZS planting machine the surface humus was mixed with mineral soil.
e/ Relatively homogenous distribution of the surface humus before cutting was disturbed.
f/ The total amount of surface humus increased /from 50,000 to 72,840 kg per ha/. This difference is accounted for by the logging method applied.
g/ When felling trees - needles, dry twigs, shoots and branches break and remain on the soil surface.

In addition to destruction processes in the surface humus due to logging operations attention was paid to the rate of decomposition of organic residues on the felled area caused by changed bioclimatic factors.
In view of the fact that the surface humus displayed great variability in bulk density a model trial plot was established with the same density of all layers /L-, F- and H-layer/ of the surface humus as under the stand and the loss of humus bulk density was observed on the plot. Three years after felling the largest loss was recorded at the L-layer /litter/, i.e. 64%, at the F-layer the loss amounted to only 25% whereas at the H-layer /mull/ partial accumulation of the organic matter was recorded.

3/
The change of physical properties in soil after clear felling can indirectly affect also nutrient cycling particularly by decreasing the permeability of soil profile for water and by affecting the occurence of plant species.
Immediately after felling bulk density of the soil surface layer was markedly increased especially on the skidding trail, i.e.from 1.27 to 1.79 and on the other area from 1.27 to 1.57 .

Due to the development of ground vegetation and its root systems on the felled area the value of bulk density gradually decreased. After 4 years, e.g. the value of bulk density on the skidding trail decreased from 1.79 to 1.72 .This change is not important, but in places where the genera *Juncus* and *Carex* occured, this value decreases to 1.50 . In the other area there is no such significant difference in this change after 4 years, between the areas with sod of herbs, and outside these areas the bulk density amounts to 1.43 and 1.45 . It can therefore be assumed that within 8-10 years the bulk density will reach its initial value. The development of porosity was also studied. It was found to decrease significantly particularly on the skidding trail, i.e. from 52.15 to 32.19 %. On the majority of the skidding trail surface its recovery was very slow /from 32% in 1977 to 35% in 1981/,only on the surface affected by the herb sod this value significantly increased /to 44%/. On the remaining surface apart from the skidding trail, the effect of the herb sod is here also apparent.
A similar effect was observed with minimum soil aeration.

4/
The developed heterogeneity of the soil surface hinders studies of the migration of elements in the soil solution. That is why it is necessary to study also this problem on model profiles. On the basis of preliminary results it is possible to conclude that the pH of lysimetric water intercepted under the surface humus on the felled area was lower in the first two years as compared with water under the undisturbed stand. In the third year after felling, the pH of lysimetric water on the felled area and under the stand was approximately balanced. The decrease of pH of water from surface humus on the felled area is evidently connected with the beginning of mineralization of organic matter with a high production of CO_2. The concentration of carbon in lysimetric water under surface humus on the felled area in the course of three years after clear cutting was lower than in the water under the stand. A similar tendency appeared also with the concentration of calcium and nitrate nitrogen. This phenomenon can be caused due to the different hydrological conditions on the felled area /dilution of soil solution/. The migration rate of organic substances was higher on the felled area even in the third year after felling.

5/
As given above, the losses of the individual elements were highest in the first and second year after cutting. This process is hampered by a gradual growth of the herb vegetation which is of dominant importance in the newly formed cycling of elements within the atmosphere, plant cover and soil.
In 1977, the year of felling, the herb vegetation in the stand under study was very sparce and thus also the supply of nutrients accumulated in this ecosystem component. In the total balance of cycling of elements these values are quite negligible. In the first year after felling /1978/, no analysis of the herb vegetation on the felled area was done as it appeared only sporadically in places where the soil was compressed by machinery /Juncus conglomeratus/. A detailed analysis was carried out in the 2nd and 3rd years after felling /Vašíček, personal communication/. On the basis of the analysis the supply of elements was determined which the herb vegetation gradually received into the cycling on the felled area. It is possible to say that the period decisive for the fixation of elements by herbs occured in the 3rd year after felling, i.e., that assumptions presented in the literary survey were fully confirmed in the present experiment as well.

Thus e.g., in the whole biomass of the spruce stand 430 kg of nitrogen per ha was accumulated, the accumulation in the herb biomass on the felled area in the 3rd year after felling amounted to 226 kg, which is 52%. At the same time it is necessary to take into account that a great part of the herb biomass form the annual litterfall so that the return of some elements in this stage of development of the forest stand by far exceeds the annual return of elements in the litterfall in a mature spruce stand.

In the 3rd year after felling the dominant herb in the felled area became Chamaenerion augustifolia which out of the total herb dry biomass of 11.4 t.ha^{-1} amounted to 4 t, i.e. 35%, even though in 1979, in the second year after felling, out of the total dry biomass of about 0.5 t.ha^{-1} amounted to 60 kg, i.e. 12%. With a

Tab.1 Development of physical properties of soil after clear cutting

physical properties	place of sampling	date of sampling				
		VI - 1976 before felling	VI - 1977 immediately after felling	VI - 1979	V - 1981	XI - 1981 under herb sod
bulk density	on skidding trail	1.27	1.79	1.68	1.72	1.50
	on other area	1.27	1.57	1.51	1.45	1.43
porosity	on skidding trail	52.15	32.19	35.36	35.14	43.90
	on other area	52.15	40.65	41.69	45.70	46.80

Tab.2 Development of supply of elements in biomass of herbs on felled area after felling a spruce stand

/ 1977 - year of felling / element /kg.ha^{-1}/

period	N	P	K	Na	Ca	Mg	S	Mn	Fe	Zn	Cu
1977	0.2	0.02	0.03	-	0.1	0.02	0.02	-	0.03	-	-
1979	6.6	0.8	6.8	0.1	0.8	0.7	0.5	0.7	0.4	0.02	0.2
1980	226.3	28.5	180.8	1.3	31.6	24.6	13.3	17.5	6.4	0.9	11.8

relatively high concentration of nitrogen /3.45% aboveground and 1.23% underground part/, phosphorus /0.48% aboveground and 0.25% underground part/, and potassium /2.32% aboveground and 1.99% underground part/, *Chamaenerion augustifolia* is of dominant importance also in the cycling of these nutrients on the felled area.

CONCLUSIONS

In an experimental research station in the region of the Drahanská Uplands, the effect was studied of clear cutting in a spruce stand on the cycling of nutrients. It was found that :

/1/
logging caused a loss of 1038 kg of calcium, 570 kg of nitrogen, 510 kg of potassium, and 103 kg of phosphorus per ha

/2/
the soil surface humus was destructed, the heterogeneity of its distribution over the area increased. A considerable decrease in mass of the individual surface humus layers was observed in layers L and F

/3/
the compression of soil by machinery when skidding timber from the felled area increased bulk density of the soil and decreased its porosity. The recovery of these properties is slow, especially due to the development of the root system of the herb vegetation

/4/
due to mineralization of organic matter on the felled area, the pH of the soil solution decreases. The migration of elements on the felled area increased particularly in the 1st and 2nd years after felling

/5/
the development of the herb vegetation with *Chamaenerion augustifolia* as a dominant considerably influenced nutrient cycling in the felled area in the 3rd year after felling.

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